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NUMERICAL APERTURE.

Dr. MARSHALL D. EWELL, Chicago, Illinois.

It is not proposed in this paper to enter upon any theoretical discussion, but to give the results of actual measurements of the aperture of such objectives of different makers as I have been able to procure for that purpose. These measurements were made with an Abbe

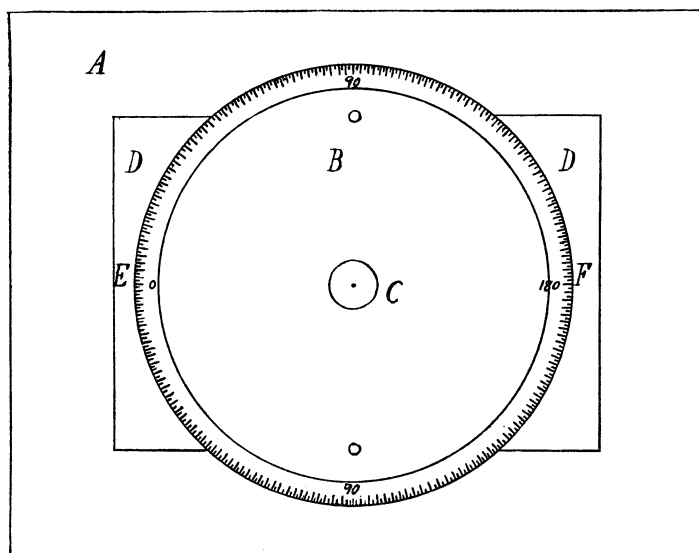


FIG. I.

apertometer, which will be found figured and described on page 24 of Zeiss' English Catalogue, 1891, as "No. 2." (See also Jour. Roy. Mic. Soc., Jan., 1878, p. 19; id., 1880, p. 20)

I intended to repeat the measurements on another apertometer of my own construction and to include the results in this paper, but the pressure of professional duties has prevented the completion of

this work in time for this meeting. A description of this piece of apparatus may, however, not be inappropriate. (See Fig. 1.)

(A) represents an iron plate twenty inches square and one-half inch in thickness, planed as flat as possible on its upper surface; (B) represents a brass circle thirteen inches in diameter, graduated to one-half degrees and turning around its center (C); (D) represent two opposite verniers, reading to single minutes of arc.

In practice, however, these are entirely unnecessary, as the unavoidable errors of measurement much exceed the least count of the verniers. The circle is read, therefore, simply to one-half degrees or, if desired, by estimation to three minutes of arc.

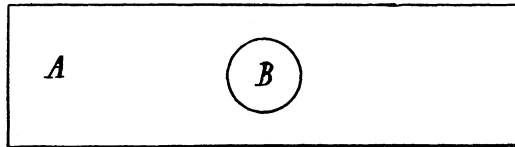


FIG. II.

(A) represents a brass slide with a small hemispherical lens (B), burnished into an opening in its center. The center of this lens is indicated by a very small circle marked on its plane surface with a diamond while in the chuck on which it was turned up. This portion of the apparatus was made for me by Spencer & Smith, of Buffalo, New York.

To use this instrument the stand with the slide figured above in position on its stage, is placed on the circular disk (B), with the center of the hemispherical lens as nearly over the center (C) as possible. The objective whose aperture is to be measured is focused on the center of the hemispherical lens, the microscope being in a horizontal position. A light—*e. g.*, a small incandescent lamp—is then placed at a convenient distance in front of the microscope, and the microscope and disk revolved, and the angle of aperture in crown glass read off, as with other apertometers. The eccentricity is eliminated by taking the mean of the two readings at (E) and (F).

I should have been glad to include more objectives in this table, but have been unable to procure them, some dealers apparently being unwilling to submit their objectives to the test proposed, since no attention was paid to my letter requesting the loan of objectives for said purpose. The table needs no explanation. No tests of the objectives were made other than to determine their aperture.

TABLE DESCRIBING OBJECTIVES.

Maker.	No.	Description.	Aperture claimed by maker.	Aperture as measured.	No. of readings.	Owner of objective.
Bausch & Lomb Optical Co.	None	Professional 1''	36°	30°	4	M. D. Ewell, Chicago.
Do.	"	½ opaque illuminator.	65°	61°	3	"
Do.	"	2'' First class	22°	21°	4	"
Do.	"	¼ Student's; Catalogue No. 608.	75°	70°	3	Mrs. W. H. Bullock, Chicago.
Do.	"	⅓ Student's; Catalogue No. 611.	110°	95½°	3	"
Do.	"	¼ opaque illuminator.	115° *	88°	1	M. D. Ewell, Chicago.
Do.	"	First class ⅙	140°	114°	3	"
Do.	"	First class 1⁄16	110°	111°	3	"
Do.	"	⅙ hom. im.	143 N. A.	128 N. A. †	3	W. H. Summers, Chicago.
Beck	"	First class ⅓	100°	98°	1	"
Crouch	"	1 inch	25°	24°	1	"
Grunow	"	⅙ inch	140°	{ 150° closed 147° open	2	Dr. H. M. Farr, Mt. Pleasant, Iowa.
Gundlach	"	⅙ hom. im. "E"	{ 136° B. A. = 141 N. A. †	{ 139 N. A. = 132° 16'	3	Prof. E. S. Bastin, Chicago.
Hartnack	"	½ inch	40°	47°	1	W. H. Summers, Chicago.
Leitz	"	No. 3 dry (18 mm.) . . .	N. A. 0.28	N. A. 0.28	4	Richards & Co. (Ltd.), Chicago.
Do.	"	No. 7 dry (32 mm.) . . .	N. A. 0.85	N. A. 0.88	3	"
Do.	5141	1½ oil im.	N. A. 1.30	N. A. 1.28	3	"

Spencer & Co.	637	$\frac{1}{4}$ Student's	94°	3	M. D. Ewell, Chicago.
Do.	654	$1\frac{1}{16}$ hom. im.	130° B. A.	1.36 N. A.	4	"
Do.	None	$\frac{2}{3}$ hom. im.	125° B. A.	1.32 N. A.	3	"
Spencer & Smith	856	New dry First class	130°	126°	4	"
Do.	862	$1\frac{1}{16}$ New dry First class	150°	167°	3	"
Do.	884	$1\frac{1}{16}$ hom. im. (new formula).	138° B. A.	N. A. 1.41	3	"
Do.	886	1 inch.	33°	33 $\frac{1}{2}$ °	3	"
Do.	893	$\frac{1}{2}$ inch.	70°	7 $\frac{1}{2}$ °	3	"
Do.	997	$1\frac{1}{2}$ hom. im. (new Professional).	1.00 N. A.	0.97 N. A.	3	M. D. Ewell, Chicago.
Tolles	None	$\frac{1}{16}$ hom. im.	{ B. A. 120° = N. A. 1.32	{ N. A. 1.31	3	"
Do.	"	2" solid	Unknown	12 $\frac{1}{2}$ °	1	W. H. Summers, Chicago.
Do.	"	$1\frac{1}{2}$ water im.	"	{ 0.99 closed 0.90 open	2	Jno. H. Choate, Salem, Mass.
Wales	"	$1\frac{1}{2}$ inch.	20°	20°	1	Preston, Chicago.
Do.	"	$\frac{1}{2}$ inch.	60°	51°	1	"
Do.	"	$\frac{1}{4}$ inch.	100°	97°	1	"
Zeiss	710	A. A. $\frac{3}{4}$	36°	31°	4	M. D. Ewell, Chicago.
Do.	282	C. C. $\frac{1}{4}$	90°	102°	3	"
Do.	194	$1\frac{1}{8}$ hom. im.	N. A. 1.27	1.27 N. A.	3	"

* So stated by Prof. W. A. Rogers, who purchased it for me.

† Approximately.

‡ Collar at 1°, best point of adjustment.